Space Technology Research Grants

Calibration and Validation for Constellations of Remote Sensing CubeSats with Microwave Radiometers

Completed Technology Project (2016 - 2019)

Project Introduction

Miniaturized microwave radiometers deployed on nanosatellites in Low Earth Orbit (LEO) are now demonstrating the ability to provide science-quality weather measurements, such as the 3U Micro-sized Microwave Atmospheric Satellite-2A (MicroMAS-2A). The goal of having cost-effective miniature instruments distributed in LEO is to field constellations and improve temporal and geospatial coverage. The Time-Resolved Observations of Precipitations structure and storm Intensity with a Constellation of Smallsats (TROPICS) is a constellation of six 3U CubeSats, based on MicroMAS-2A, scheduled to launch in 2020. Each CubeSat hosts a scanning 12-channel passive microwave radiometer. TROPICS will provide increased temporal resolution of less than 60 minutes compared to larger satellites in polar orbit such as NOAA-20 with the Advanced Technology Microwave Sounder (ATMS), which has a revisit rate of 7.6 hours. [1] The TROPICS rapid refresh rate will provide high value investigations of inner-core conditions for tropical cyclones. [2] Calibration for CubeSats presents new challenges as standard blackbody targets are too bulky to fit on CubeSats. Instead, we use internal noise diodes for calibration on CubeSats. The Global Precipitation Measurement (GPM) Microwave Imager (GMI) instrument has shown noise diodes to be very stable on orbit [3], but they have not been tested on-orbit at TROPICS frequencies. In order to provide state of the art calibration for CubeSats, methods must be developed to track and correct noise diode drift. We will quantitatively determine the radiometric accuracy of MicroMAS-2A and compare it to state of the art instruments to provide an assessment of CubeSat performance. Radiometric accuracy is determined by using the Community Radiative Transfer Model (CRTM) and the Rosenkranz Line-by-Line (LBL) Radiative Transfer Model (RTM) with inputs from GPS radio occultation (GPSRO), radiosondes, and Numerical Weather Prediction (NWP) models in order calculate simulated brightness temperatures that are used as the ground truth. We perform on-orbit calibration corrections using histogram matchups between MicroMAS-2A and the MicroWave Humidity Sounder (MWHS)-2 on the Chinese weather satellite FengYun (FY)-3C. The double difference technique is then used to compare MicroMAS-2A performance to ATMS. We also develop a novel method of calibration for CubeSat constellations such as TROPICS by incorporating solar and lunar periodic intrusions as an additional source of information to counter noise diode drift. These solar and lunar intrusions occur as well for existing satellites hosting microwave radiometers in polar orbits, but are much more infrequent than for the TROPICS constellation's scanning payload and are typically treated as an observational and calibration limiting constraint. The higher rate of occurrence of intrusions motivates the novel idea of using the intrusions to support calibration. An algorithm is developed to compare expected effective brightness temperature from solar and lunar measurements to actual measured brightness temperatures, and the algorithm is tested using ATMS lunar intrusion data. In addition, we develop an architecture for TROPICS to track noise diode drift. The frequency of single difference matchups, double difference matchups using both intra- and inter-

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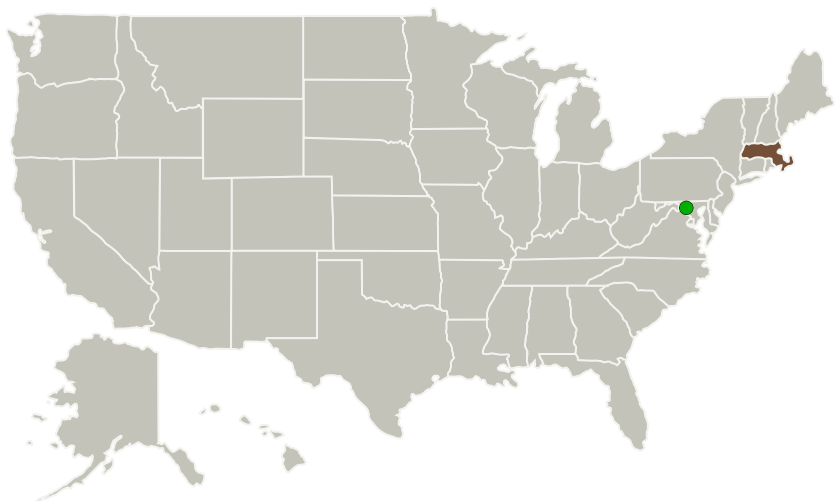
Simultaneous Nadir Observations (SNO), and solar and lunar intrusions is determined. The impact of orbital parameters and phasing on direct radiance validation opportunities is also studied.

Anticipated Benefits

This research will advance the technology of formation flying a constellation of CubeSats and will contribute to analysis of how to improve BRDF measurements from spacecraft.

Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
Massachusetts Institute of Technology(MIT)	Lead Organization	Academia	Cambridge, Massachusetts
Goddard Space Flight Center(GSFC)	Supporting Organization	NASA Center	Greenbelt, Maryland

Primary U.S. Work Locations
Massachusetts

Organizational Responsibility

Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

Lead Organization:

Massachusetts Institute of Technology (MIT)

Responsible Program:

Space Technology Research Grants

Project Management

Program Director:

Claudia M Meyer

Program Manager:

Hung D Nguyen

Principal Investigator:

Kerri Cahoy

Co-Investigator:

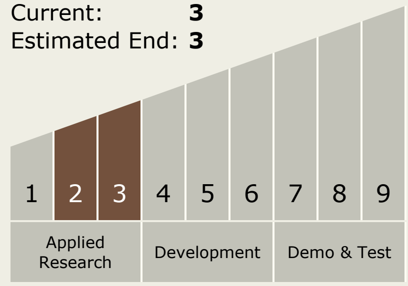
Angela Crews

Project Website:

https://www.nasa.gov/strg#.VQb6T0jJzyE

Technology Maturity (TRL)

Start: **2**
Current: **3**
Estimated End: **3**



Technology Areas

Primary:

- TX08 Sensors and Instruments
  └ TX08.2 Observatories
    └ TX08.2.3 Distributed Aperture

Target Destination

Earth